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Differences in local perceptions about climate and environmental changes among residents in a small community in Eastern Siberia

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ABSTRACT

This study aims to deepen the understanding of the impact of climate change on human societies in arctic areas, and to consider the adaptations made by these societies. Previous studies have focused on local perceptions, which should be key to developing processes and solutions, by taking into consideration all stakeholders in order to integrate their views with scientific knowledge. We aim to discern the appropriate quality of perceptions: in other words, what range of perception is needed to ascertain adaptation strategies. This study clarified different perceptions of climate change among local residents in a small community in eastern Siberia where various environmental changes, such as permafrost thaw, have occurred in recent years or are in progress. Structured questionnaire surveys and unstructured interviews were conducted in Khayakhsyt Village, Sakha Republic. The results showed that drought is a serious, focal climatic event in this area, and that local residents have historically adapted to this event by increasing the number of artificial ponds extant using their developed ethno-geographical knowledge of the thawing water stream. Thus, even under the recent precipitation increase, not all participants mentioned the observed climate trends, while the memory of drought persisted within and influenced community perceptions.

1. Introduction

High latitude areas have been strongly affected by recent climate changes (Vaughan et al., 2013). In addition to ice sheet and permafrost thaw due to rising temperatures, fluctuations of annual rainfall also have a significant impact upon the natural environment and lifestyle of residents in these areas (Vaughan et al., 2013). Global society has established adaptation strategies involving the development of new technologies, livelihood methods, social policies, and cultures to cope with recent climate changes and frequent meteorological disasters. Meanwhile, the processes and mechanism of environmental changes vary by physical condition and sociocultural setting, from area to area. To achieve adaptation strategies, various stakeholders need to confront issues such as land degradation and permafrost thaw that have emerged as indigenous phenomena, and share information among stakeholders.

Climate changes have resulted in a complex relationship between the physical changes that are actually happening in specific locations and the changes in the perceptions of climate and the environment held by the public (Anisimov and Orttung, 2019). As classic research on environmental cognition has argued, the public's environmental perceptions are an important factor in constructing individual behaviors and the relationships between the natural environment and local residents' physical environmental condition. Therefore, as the climate and environment change in different ways based on geographical locations and physical condition, detailed data are required on the contrast between what is happening in each location and the perceptions of local residents.

Public perception strongly affects the process of national and regional policy making. Each region or country has a different political environment for making climate change policy. Previous research has shown that citizens of different countries differ in their ways of perception relating differences to their environment (Capstick et al.,

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2015; Lee et al., 2015; van der Linden, 2015), and some studies have found variations in perceptions on climate changes within a single country. For example, one study in the U.S. and Western Europe found that 63% of Americans believe in global warming, but there is considerable variation in perceptions among countries, with the proportion of climate change believers ranging from 43% to 80% (Howe et al., 2015). In the Russian case, Anisimov and Orttung (2019) found that the population considers climate and environmental changes to be the results of local rather than global drivers and are unprepared to act against the changes.

Even within a village society, there are smaller groups that perceive climate changes differently, and their perceptions are influenced by a wide range of variables, such as local weather events, personal experience, gender, and education (Ayal and Filho, 2017; Wolf et al., 2013). Large gaps between the perceptions of researchers and local residents also sometimes exist. To develop a society that is resilient against climate change, the sharing of information about patterns of perceptions and the factors affecting the formation of perceptions among stakeholders is an important approach.

In earlier studies about local adaptation to climate change in eastern Siberia, scientists revealed that residents are continuously adapting to the local environment, which is characterized by permafrost, by modifying their livelihoods, culture, and social system in the background of historical processes (e.g. Crate et al., 2017) and recent changes (e.g. Takakura, 2016). On the basis of anthropological studies in the Sakha community, some researchers also emphasized the importance of local perceptions in considering coping strategies regarding climate change (Crate, 2008, 2011, Crate and Fedorov, 2013).

This study aims to deepen the understanding of the impact of climate change on human societies in permafrost areas. It also examines interactions between local people and their environment in the process of adaptation to an indigenous environment. This approach contrasts previous studies by focusing not only on local perceptions, which should be key to finding the process and solutions, but also taking into consideration all stakeholders in order to integrate their view with scientific knowledge. We would like to discern the appropriate quality of perceptions: in other words, what range of perception should be used to assess the adaptations.

The study clarifies the different perceptions of climate change held by local residents in a small eastern Siberian community where thick permafrost has developed, by examining their adaptation strategies to environmental changes. Section 2 provides the methodology and background information of the target area and indicates how the climate is changing in that area. People's perceptions of climate change are obtained via a questionnaire survey and its categories were shown in section 3. We then show that drought is one of the most significant objects of local residents' perceptions. Section 4 clarifies the meaning of *drought* for local residents by showing qualitative information about drought perception and the residents' historical interactions in coping with drought events. Finally, the relationships between these sections are discussed in the Discussion (section 5), and the future implications are discussed. Factors relating to the construction of perceptions were revealed by analysis of quantitative descriptive data particularly focused on the residents' historical interactions related to coping with weather events.

2. Methods and data

2.1. Study site

The target area was Khayakhsyt Village, located in the central part of Sakha Republic in eastern Siberia, Russia. Most of the area of eastern Siberia is in a continuous permafrost state (Brown et al., 2002). The characteristic permafrost landscape feature of the central and western lowlands of the Sakha Republic is *alaas* (in the Sakha/Yakut language, known as "alas" in Russian and English), which is a plate-like grassland with lakes in the deepest part (Crate et al., 2017). The formation of *alaas* is thought to have taken about 3000–9000 years; they have a diameter of 100 m–15km (Crate et al., 2017), and have played an important role as a source of pasture and drinking water: the Sakha word *alaas* means "meadow in the forest" (Crate et al., 2017). Today, approximately 16, 000 *alaas* are found in the lowlands of the Sakha Republic (Bosikov, 1991).

Vegetation in the Republic of Sakha is roughly divided into a taiga (coniferous forest) that occupies most of the area, a largely treeless permanently frozen tundra, and a transition zone between the taiga and tundra (Crate, 2006). Hydrologists call this the "vegetation-frozen soil system," and the challenge is to investigate how the ecosystems that have been sustained over the past thousands of years have now changed due to global warming (Zhang et al., 2011).

On the basis of its topographical and landscape features, a study site was selected that represented a typical area from the viewpoint of permafrost and *alaas* distribution. The study site, Khayakhsyt village, is located in the Churapchinsky district (N61.43359°, E131.56302°), Sakha Republic. The particular characteristics of permafrost in this district are its thickness of 150–500 m and the presence of numerous ice wedges (Ivanov, 2007: 79). Due to the recent climate changes, comprising several factors such as temperature changes and an increase in rainfall, a widespread warming of the surface layer of the permafrost in this region has been induced. Romanovsky et al. (2010) reported changes of ground temperature at some observation points in Russia (including in the northern part of the Sakha Republic), most of the permafrost observatories in Russia show substantial warming of permafrost over the last 20–30 years, typically from 0.5 to 2 °C of warming at the depth of zero annual amplitude. Iijima et al. (2010) reported that consecutive positive anomalies of snow depth and rainfall, which occurred widely in the central and southern Lena River basin during a three-year period from 2005 to 2007, increased soil moisture and appeared to have altered the active layer thermal properties. Further, Saito et al. (2018) observed the development of thermokarst that was caused by the thawing of permafrost and found that the thawing accelerates in Churapchinsky district.

According to meteorological data from Churapcha, a district administrative center around 47 km from the center of Khayakhsyt village, the mean annual temperature is −11.5 °C, while monthly mean temperatures for January and July are −44.0 °C and 18.1 °C, respectively (Saito et al., 2018). Fig. 2 shows the annual rainfall in Churapcha and Yakutsk (the capital city of the Republic) from 1950 to 2014. The mean annual rainfall ranged from 129.5 to 374.0 mm in Churapcha and 147.7 to 326.2 mm in Yakutsk. This indicates that the precipitation in the Sakha Republic is relatively low and fluctuations in annual rainfall are high. Regarding precipitation trends, rainfall amounts have been relatively high in the last 10 years; the amount of annual precipitation over the past 30 years was 2303.6 (1985–94), 2192.3 (1995–2004), 2525.6 (2005–14) in Yakutsk, and 2184.6 (1985–94), 2385.2 (1995–2004), 2807.1 (2005–14) in Churapcha. The mean value with standard error of annual rainfall in recent 30 years was 230.4 ± 15.0 (1985–94), 219.2 ± 18.1 (1995–2004), 252.6 ± 14.7 (2005–14) in Yakutsk, and 218.5 ± 19.1 (1985–94), 238.5 ± 12.0 (1995–2004), 280.7 ± 16.1 (2005–14). However, between 1950 and 2014, there were 17 occasions where the annual precipitation was under 200 mm (1954, 1959, 1962, 1963, 1969, 1972, 1973, 1980, 1985, 1986, 1987, 1990, 1991, 1992, 1998, 2001, and 2002), which shows that a year with extremely low precipitation occurs two to four times every 10 years (Fig. 2). These mean precipitation amounts are equivalent to the mean amounts in central Mongolia, an arid to semiarid environment (Batima et al., 2005). Thus, the local meteorology of the Sakha Republic is substantially dry.

The geographical area of Churapchinsky district is 12,600 km^2, and the population of this district is 21,161 (Rosstat, 2018). The dominant ethnic group in the area is the Sakha. Churapcha is a central town in this district with a population of 10,177 (Rosstat, 2018). The study site,

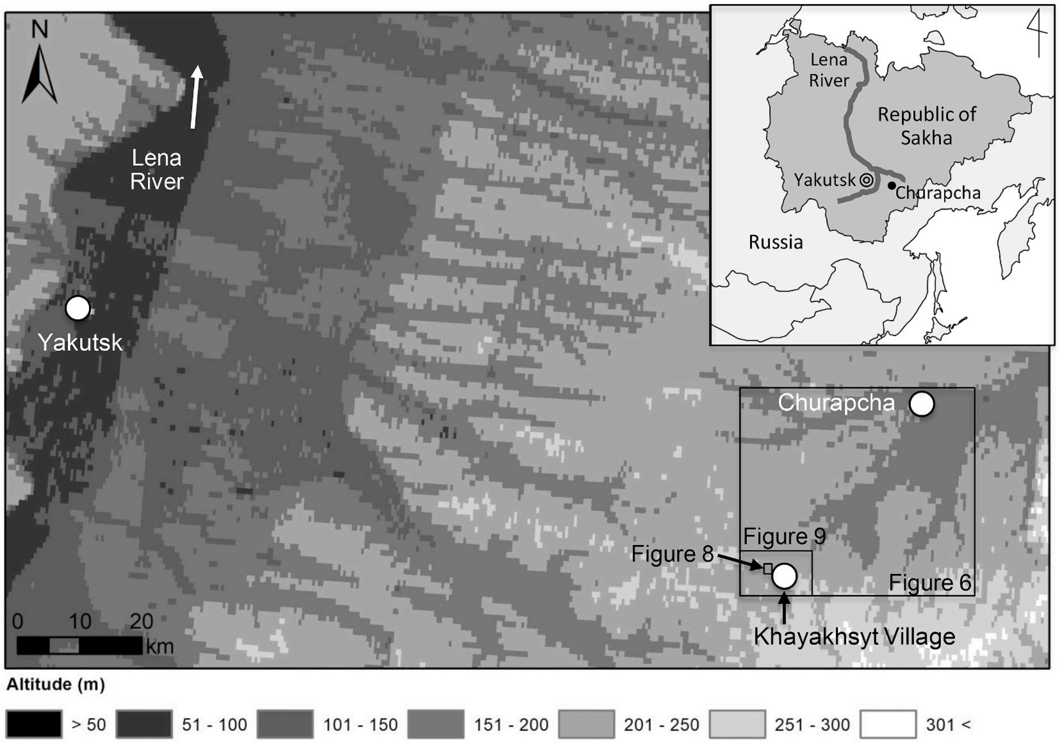

Fig. 1. Research area. Background map made by ArcGIS using a DEM data of GTOPO30 provided by U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center.

Khayakhsyt village, is medium-sized with a population of 536 people (Rosstat, 2018).

The territory of the Republic of Sakha is 3.0855*10^6 km^2 (18% of the whole country), making it the largest "federal constituent" of Russia (that is, the regions, republics, counties etc., that constitute the Russian Federation). According to the 2018 official statistical data of the Russian Federation, the population of the Sakha Republic (Yakutia) is 964,330 with Sakha (Yakut) and Russians accounting for the majority, although there are also indigenous ethnic minorities living in the north (Demographic Yearbook of the Republic of Sakha (Yakutia), 2018). Thus, the Republic of Sakha is characterized by low population density (0.31/km^2), which is significantly lower than in Russia as a whole (8.6 people) or in the Far Eastern Federal District (1.0 people). The population density of Churapchinsky district is 1.68/km^2, while that of Khayakhsyt village is 1,22/km^2 (over 439.25 km^2).

According to Sakha ethnologists, the Sakha people can be roughly divided into four regional groups: the Lena Amga group living in the central part; the Vilyuy group in the western part, the Olekma group in the southwest part, and the group in the northern part, including the Arctic Circle (Ivanov, 2000: 665). Khayakhsyt village is home to the central Lena Amga group. The area of Sakha includes Yakutsk, the capital of the Republic of Sakha, an area that, according to the mythology of ethnic migration, is considered to be the hometown of typical Sakha culture. The first historical mention of Khayakhsyt village dates back to the 1630s; according to historical tax records from the region, the place name Khayakhsyt was derived from the name of a dominant local Sakha chief (Borisov, 2010).

By the beginning of the 1940s, 1100 people lived in the territory of Khayakhsyt village; however, the Second World War caused considerable demographic damage to the local population as many young men were drafted into the army and killed in battle. The forced relocation of a part of population of the Churapchinsky district to the northern regions of Yakutia by the Soviet authorities also caused great damage. This deportation was due to the need to withdraw the population from areas of drought and/or under threat of starvation. It was assumed that some of the collective farms from Churapcha would be moved to the north to shift production to fishing, but due to a lack of preparation for that the operation, most of the deportees died from hunger, disease, and poor living conditions. Before the Second World War, the population of Churapchinsky district was about 17,000 people, as of January 1, 1943, 7934 people remained there. A total of 388 people were forcibly resettled from Khayakhsyt village to the north, most of whom never returned (Popov et al., 2005).

As is well known in the history of Soviet agriculture policy, the enhancement of collectivization that transformed collective farms into state farms was implemented in the Sakha Republic in the 1960s. The Sakha people in central Yakutia, who had traditionally lived separately in *alaas*, with several families practicing transhumance, were forced by this policy to live in state-sponsored villages. In parallel, the state farm system was introduced and provided various jobs for those people. Subsequent policies such as deforestation and the enlargement of agricultural land in the Churapchinsky district, including Khayakhsyt village, followed in the 1970s and 1980s. The state farm and village administration developed large-scale oat and rye fields and an airstrip in this region before the end of the socialist regime.

The traditional life calendar of Sakha people living in rural areas is oriented toward livestock keeping and fishing from summer to autumn and hunting from winter to spring. The main industry of the district is cattle and horse breeding. In the village there are agricultural cooperatives, 15 large farms, and 151 personal farms (Khaiakhsytskii nasleg, 2015). Many of Khayakhsyt village's residents are part-time farmers who have some work in the village to earn cash income, which they supplement by growing potatoes and summer vegetables in a vegetable garden at home and raising one or two cattle in order to be self-sufficient. Residents have private spaces in *alaas* that are scattered around the village, and, in the summer season, they produce hay for the winter feeding of cattle. On the other hand, some inhabitants operate medium or large-scale "managements" as commercial farmers.

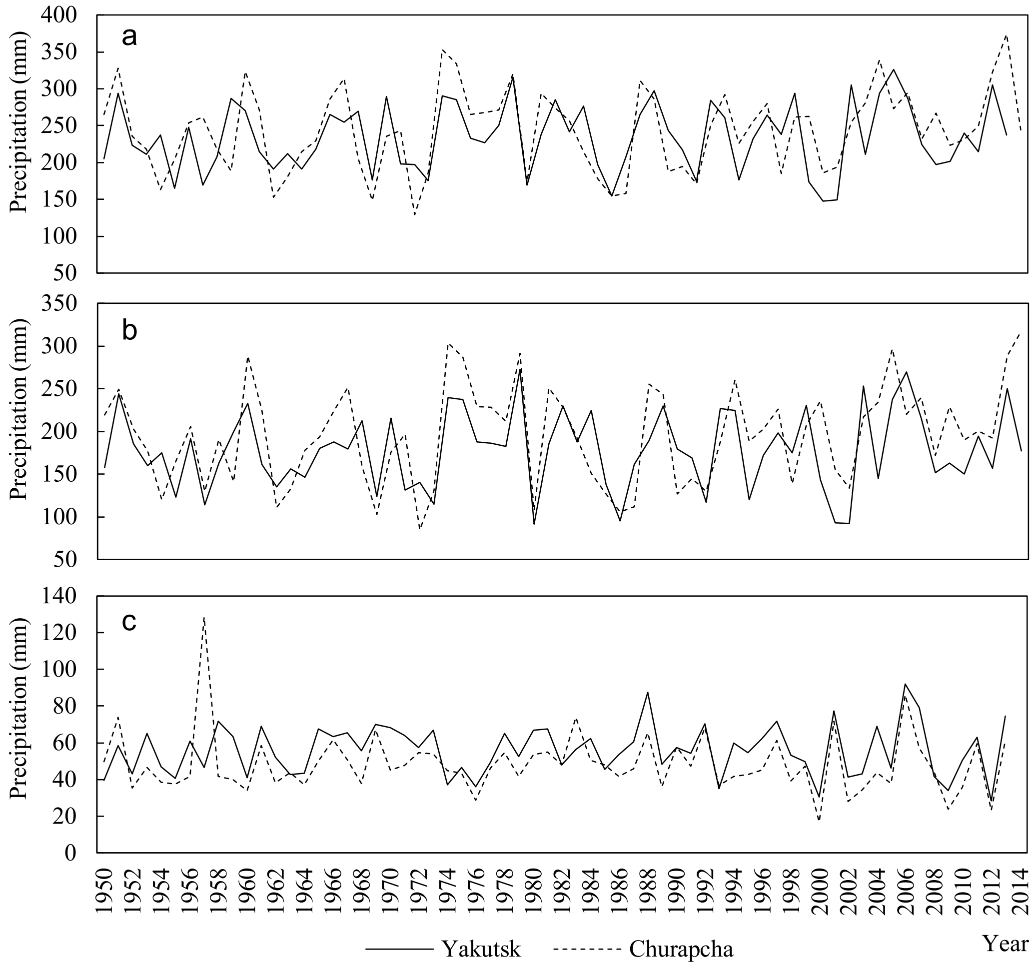

Fig. 2. Fluctuations in precipitation in Yakutsk and Churapcha from 1950 to 2014. a: Annual precipitation, b: Precipitation of summer season (May to Oct), c: Precipitation of winter season (Nov to Apr).

2.2. Data sampling

Field surveys were conducted in September 2016 and March and September 2018. First, a preliminary interview survey and group discussion were conducted in Churapcha and Khayakhsyt village in September 2016. To collect data about climate and environmental changes in the area, the group discussion was held in Churapcha town, in which five local adult residents (two men and three women) participated. Thereafter, a structured survey questionnaire was developed based on the information obtained from the preliminary surveys and the methodology of Ayal and Filho (2017), who surveyed the perceptions and impacts of climate variability in rural areas in Ethiopia through a survey questionnaire.

The main survey was conducted in Khayakhsyt village in March and September 2018. A mixed research approach was used, combining qualitative and quantitative methods: First, the questionnaire survey was conducted in March to clarify local residents' perceptions about climate changes, then, in September, interviews were conducted to examine the results of these surveys.

The questionnaire comprised four parts, including questions on (1) respondents' basic information, (2) their perceptions of climate changes, (3) the impacts of climate changes on their households economy, and (4) free description of the methods of adaptation to these changes. The results of parts (3) and (4) are not shown in this paper, where we mainly focus on the results of part (2). In part (2), quantitative data on farmers' perceptions of climate changes during the previous decade were collected from sample households using Likert-scale typology questions (5 scales). The questionnaire sheet was written in the Sakha language, and an English translation of part (2) is summarized in Table 1.

Regarding sampling of respondents the researchers first informed the residents of the implementation of the questionnaire survey via administrators in the community assembly before commencing. Sample respondents were then selected using two methods: a stationary survey administered at a village primary school and a visiting survey in which researchers randomly visited houses in the village to collect data. The researchers explained the purpose and contents of the questionnaire, and then informants answered each question. To avoid developing biased responses, we respected the self-motivated participative nature of the survey and selected only informants who agreed through informed consent.

The socio-economic and demographic characteristics of respondents are summarized in Table 2. Of the 308 village residents over 15 years old, 56 persons (18%) in 51 households were selected for a comparatively similar degree of sample distribution as regards age and sex. Regarding education level, most of the respondents had graduated from secondary school and finished their specialized secondary education. More than six in ten (62%) of respondents were working or employed, and the average monthly income per household was about 36,000–50,000 rubles.

In September 2018, interviews were conducted to examine the results of the questionnaire survey. One of the authors visited village households and asked about the perceptions of climate and environmental changes, particularly focusing on the historical interaction between the Sakha people and the environment. He collected local

Table 1
Question items (QI) about climate changes.[a].

1 Changes in the temperature mode	
1.1	Annual mean temperature increased
1.2	Temperature increased in the winter
1.3	Temperature increased in the summer
1.4	Number of hot days increased
1.5	Number of cold days increased
1.6	The degree of hotness of hot seasons increased
1.7	The degree of coldness of cold seasons increased
2 Rainfall in Summer Seasons	
2.1	Rainfall amount increased
2.2	The onset of rainfall became more unpredictable
2.3	The cessation of rainfall became more unpredictable
2.4	Number of rainy days increased
2.5	The intensity of rainfall increased
2.6	The occurrence of untimely rainfall increased
2.7	Drought occurrence frequency increased
3 Snowfall in Winter Seasons	
3.1	Snowfall amount increased
3.2	The onset of snowfall became more unpredictable
3.3	The cessation of snowfall became more unpredictable
3.4	Number of snow days increased
3.5	The intensity of snowfall increased
3.6	The occurrence of untimely snowfall increased
4 Dangerous meteorological phenomena	
4.1	The frequency of strong winds increased
4.2	The frequency of strong glaze ice increased
4.3	The frequency of frosts increased

[a] The question is "What kinds of climate changes have you seen in your village over the past 10 years? Please evaluate them on a 5-point scale (totally disagree, disagree, neutral, agree, or totally agree) and put a tick in the desired row of the table."

knowledge data about water flows and the methods used to manage water resources in interviews with 6 elder residents, visited artificial ponds, *alaas*, and rivers with some participants, and recorded their geographical locations using a GPS receiver.

2.3. Data analysis

The results of the survey questionnaire on the perceptions of climate changes were reported as the mean ± standard error. To examine the general condition of each question, Kruskal–Wallis tests were applied to the two groups of questions on climate changes.

To explore the multivariate relationships among the question items, principal component analysis (PCA) and cluster analysis were applied to the scores of questions to create classes within which the members were generally alike and substantially different from the members of the other classes (De Gruijter, 1977; Webster and Oliver, 1990). The idea of cluster analysis is to statistically minimize the within-group variability while maximizing the among-group variability to produce relatively homogeneous groups. This combination of PCA and cluster analysis has also been used in some previous research across different disciplines, for example, in the multiscale characterization and classification of natural environmental factors (Yemefack et al., 2005; Fujioka et al., 2018).

The PCA was applied to a correlation matrix that was constructed by using the following 17 variables related to climate changes: QI1.1, 1.2, 1.3, 1.4, 1.5, 2.1, 2.4, 2.5, 2.6, 2.7, 3.1, 3.4, 3.5, 3.6, 4.1, 4.2, 4.3 (QIs showed in Table 1). The reason for focusing on a limited number of variables was to facilitate a clear understanding of the nature of the related perception. The variables selected by representative question items which showed relatively strong relations among others on the correlation matrix. Thereafter, three main principal components (PCs: PC1, PC2, and PC3) were extracted, and scores were calculated (PC scores = factor scores [FACs]) for each PC of each site for the cluster analysis.

By using the FACs, cluster analysis, for which we adopted optimization-based partitional clustering (nonhierarchical clustering)

Table 2
Respondents' socio-economic and demographic characteristics.

Items		No.			
		M	F	Total	%
Sex		26	30	56	100
Age	<20	0	0	0	0
	21–40	9	10	19	34
	41–60	7	12	19	34
Educ.Level	60<	10	8	18	32
	Incomplete secondary school	2	0	2	4
	Secondary school	10	11	21	38
	Specialized secondary education	10	9	19	34
	Incomplete higher education	0	1	1	2
	Higher education	7	12	19	34
Average Monthly Income (Ruble)	<36,000	6	6	12	24
	36,000–50,000	13	12	25	50
	50,000–100,000	6	6	12	24
	100,000–150,000	0	0	0	0
	150,000<	0	1	1	2
	Unwilling to answer	1	5	6	–
Working/ Employment[a] (n = 55)	Working or employed	15	19	34	62
	Unemployed	2	1	3	5
	Pensioner	10	13	23	42
Main livelihood[b] (n = 50)	Upkeep of the cattle	12	23	35	70
	Upkeep of the horses	11	21	32	64
	Hunting for forest game	14	19	33	66
	Fishing	17	22	39	78
	Picking berries, mushrooms	21	27	48	96
	Production of potatoes	22	28	50	100
	Production of vegetables in hothouses	21	28	49	98
	Haymaking	18	25	43	86

[a] Some respondents answered two categories.
[b] The person who answered, "one of main sources of the family economy," and, "it is of secondary value" for the question "How important it is for your household?" was counted as part of the answer, "it doesn't matter".

with the k-means method, was performed on the 17 questions to assist with classification. Before applying this analysis, an agglomerative hierarchical clustering analysis was conducted using these FACs, and we confirmed that all data could be divided into four categories by a dendrogram. Thus, we applied four clusters to the analysis of the optimization-based partitional clustering.

Following the cluster analysis, the mean ± standard error of all the parameters was calculated for each cluster. Kruskal–Wallis tests were then used to compare the 17 questions among the different clusters; these tests were also used to compare the wetland data and the soil data from the control crop fields. All statistical analyses were performed using SPSS Statistics software (IBM, version 24).

The information obtained from the interviews was summarized mainly via a descriptive method. The geographical data obtained by the GPS receiver was shown on satellite images and a dataset of the digital elevation model (DEM) to clarify and visualize the perceptions of snowmelt water flow and the distributions of artificial ponds. Two satellite images were used: the Worldview-2 true color image (Digital Globe) and the Sentinel-2 Band 11 (short wavelength infrared region, for mapping open-water distribution) image. Arctic DEM (Porter et al., 2018, 2 m spatial resolution) was also used, and these geographical data were overlapped using an ArcGIS software (Esri, version 10.1).

3. Results of the survey questionnaires

3.1. Perceptions of recent climate changes

The results for the mean score of each question item about the climate changes in the village are shown in Fig. 3. A high score (more than 3.00) item means that many informants chose the answers “totally agree” (weighted as score 5) or “agree” (weighted as score 4), which signifies they had a positive common perception about a question. On the other hand, a low score (less than 3.00) represents that respondents had a negative perception.

All of the results from the question items regarding atmospheric warming had high scores. The scores of “annual mean temperature increased (QI1.1)” and “temperature increased in the winter (QI1.2)” were especially high, with a mean value of 3.91 and 3.98, respectively.

Some of the mean scores of question answers about precipitation—“rainfall amount increased (QI2.1),” “the number of rainy days increased (QI2.4),” “the intensity of rainfall increased (QI2.5),” and “the occurrences of untimely rainfall increased (QI2.6)” were also high with values of 3.63, 3.39, 3.38, and 3.42, respectively. An item about the tendency of less rainfall, “drought occurrence frequency increased (QI2.7),” also recorded a high median value of 3.20, thus implying that opposite perceptions about the increase/decrease of rainfall were present among the residents of the same village. Conversely, the mean score of “the cessation of rainfall became more unpredictable (QI2.3)” was relatively low with mean values of 2.73.

All scores for each question about snowfall were less than the median value, which showed the negative perceptions of respondents. In particular, the score of items “number of snow days increased (QI3.4)” and “the intensity of snowfall increased (QI3.5)” were relatively low with values of 2.18 and 2.31, respectively. The other three questions regarding climate changes, namely, “the frequency of strong winds increased (QI4.1),” “strong glaze ice increased (QI4.2),” and “frost increased (QI4.3),” there were no specific features around the median degree, with values of 2.96, 3.02, and 3.07, respectively.

Kruskal–Wallis test comparisons among the mean scores of each question confirmed that there were significant differences between high and low mean score questions, which are shown by the alphabetical letters in Fig. 3. One of the points was characterized by the scores of two opposite perceptions in the same group: increased rainfall *and* increased drought occurrence.

3.2. Groups of similar perceptions about climate changes

3.2.1. Results of the principal component analysis (PCA)

Focusing on the characteristics of the first five PCs from the PCA of the standardized values of scores for the 17 question items, these PCs explained over 73.0% of the total variance in all cases, and the first three PCs explained 58.1%. The Eigenvalues of PC1-5 were 5.9, 2.2, 1.8, 1.5, and 1.1, respectively. The proportions of PC1-5 were 34.5%, 13.0%, 10.6%, 8.6%, and 6.3%, respectively; thus, thereafter, only the first three PCs were considered for the analysis of all cases.

Table 3 shows the coefficients matrix of the first three PCs for each variable. PC1 was related strongly and positively with the following 13 variables (over 0.50 of coefficient). These results signified that this component was mainly characterized by perceptions about increasing of

Table 3
Coefficients matrix of the first three principal components.

	PC1	PC2	PC3
3.5 The intensity of snowfall increased	**0.79**	0.13	−0.15
3.1 Snowfall amount increased	**0.75**	0.27	−0.12
3.4 Number of snow days increased	**0.73**	−0.02	0.16
4.3 The frequency of frosts increased	**0.73**	−0.01	−0.22
2.6 The occurrence of untimely rainfall increased	**0.72**	−0.44	0.12
1.4 Number of hot days increased	**0.65**	0.44	0.10
2.5 The intensity of rainfall increased	**0.64**	−0.18	0.35
2.4 Number of rainy days increased	**0.63**	−0.47	0.16
3.6 The occurrence of untimely snowfall increased	**0.62**	0.27	−0.12
1.6 The degree of hotness of hot seasons increased	**0.56**	0.42	0.15
4.2 The frequency of strong glaze ice increased	**0.56**	−0.40	−0.33
2.1 Rainfall amount increased	**0.55**	**−0.65**	0.24
1.5 Number of cold days increased	**0.52**	−0.03	−0.31
4.1 The frequency of strong winds increased	0.33	0.11	**−0.55**
2.7 Drought occurrence frequency increased	0.29	**0.63**	−0.31
1.1 Annual mean temperature increased	0.20	0.38	**0.61**
1.7 The degree of coldness of cold seasons increased	0.18	0.31	**0.69**

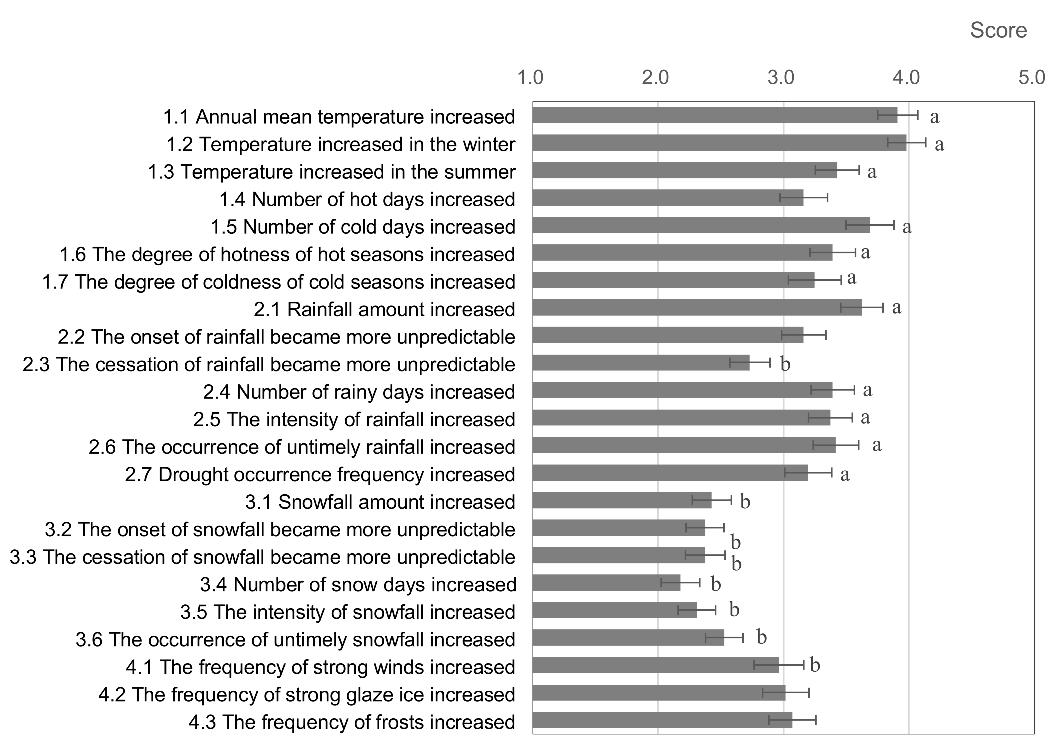

Fig. 3. Comparison of the mean scores of perceptions about climate changes by different questions. Error bars represent the standard error of the mean. Different letters indicate significant differences between questions at the 5% significance level according to Kruskal–Wallis tests.

snowfall amounts and frequencies, degree and frequency of hot temperatures, and rainfall volume. PC2 was related strongly and positively to the variable of the frequency of drought increase (QI2.7) and strongly negatively related to the variable of rainfall amount increase (QI2.1), meaning that this component was characterized by perceptions of increased drought frequency and a reduction of rainfall. Additionally, PC3 was related strongly and positively to two variables, annual temperature increase (QI1.1) and the increase in the degree of coldness during cold seasons (QI1.7), and negatively related to the variable of the frequency of strong winds (QI4.1).

3.2.2. *Cluster analysis*

The cluster analysis was applied by using the FACs of the first three PCs, and based on the results, all samples were classified into four categories through the optimization-based partitional clustering using the k-means method. The numbers (percentages) of samples in clusters A–D were 13 (25%), 11 (22%), 24 (47%), and 3 (6%), respectively. Fig. 4 shows the distribution of the FACs of the first three PCs for each cluster. Cluster A was characterized by a high score for FAC 1 and FAC 3. Cluster B featured a high score for FAC 2, and Cluster C had a high score for FAC 3 and a low score for FAC 2. Cluster D was characterized by intermediate to low scores for FACs 2 and 3.

3.2.3. *Comparison of the scores of climate changes among the different clusters*

A comparison of the results of the scores for the question items about climate changes in each cluster are shown in Fig. 5. The sample number of cluster D was too small (3 residents) for a comparison of significance; therefore, we especially focused on the significance differences among cluster A, B, and C. It was found that cluster A had significantly higher scores for most of the question items except QI4.1 (“the frequency of strong winds increased”). Cluster B was characterized by the significantly higher score of QI2.7 (“the frequency of droughts increased”) and the lower scores of questions about rainfall and snowfall increases, such as QI2.1, 2.4, 2.5, 2.6. 3.1, 3.4, QI4.2 (“the frequency of strong glaze ice increased”), and QI4.3 (“the frequency of frosts increased”). Cluster C had significantly higher scores for QI2.1 (“rainfall amount increased”) as well as “rainy days increased” (QI2.4) and “the occurrence of untimely rainfall increased” (QI2.6); however, this cluster had significantly lower scores for snowfall-related questions, such as QI3.1, 3.4, 3.5, 3.6, and the question regarding the frequency of drought increase (QI2.7).

The analysis indicates that cluster B can be characterized as including high perceptions of drought increases and lower perceptions of rainfall amount and frequency increases, while Cluster C can be seen as including high perceptions of rainfall amount increases but lower perceptions of snowfall amount increases. Cluster A involved high perceptions of most of items, such as temperature, rainfall, and snowfall increases.

4. Results of interviews about the historical interaction between the sakha people and the environment

4.1. *Drought experiences and water resource uses of local residents*

According to the interview survey, oral narratives of the local people showed that the village has experienced several droughts in their lifetimes. One female informant, who was born in Khayakhsyt village in 1947, told us there used to be a drought every 10 years, and the last occurred in 1988. Recently, she has felt it is much rainier. Many others also remembered the regional droughts. There is a large lake near Churapcha village, but it was artificially built during the time of socialism. After the 1960s' state farm rural development, Churapcha

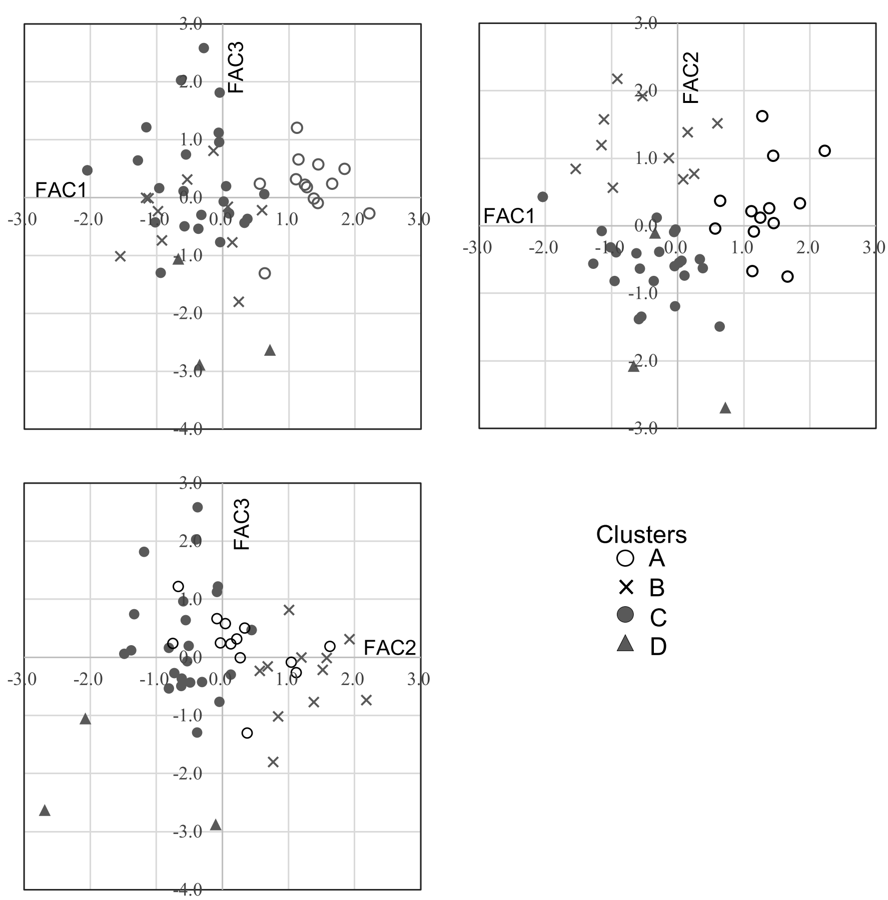

Fig. 4. Distribution of principal component score by clusters.

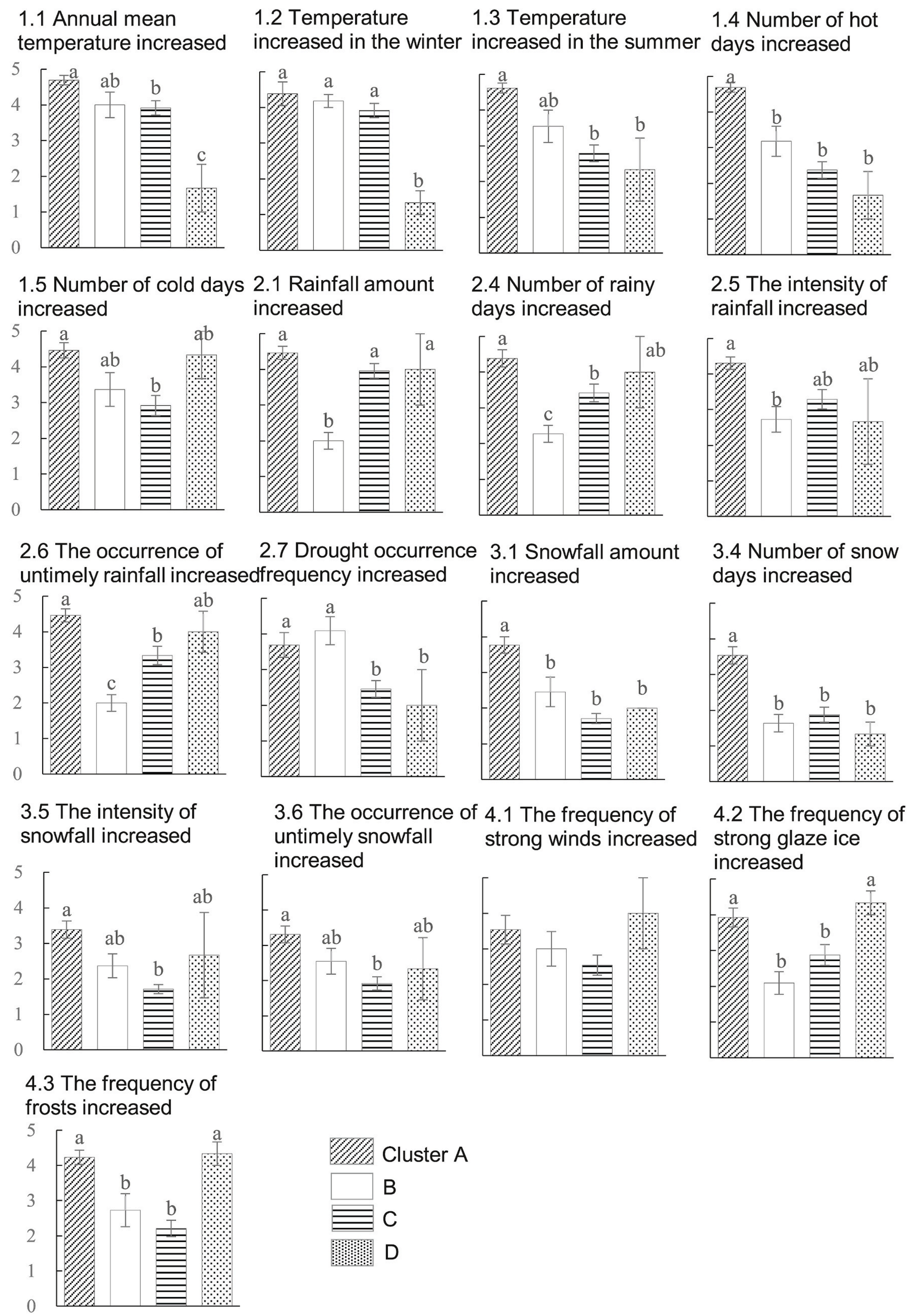

Fig. 5. Comparison of mean scores of perceptions about climate changes by different clusters and questions. Error bars represent the standard error of mean. Different letters indicate significant differences between treatments at the 5% significance level using Kruskal-Wallis tests.

village was also rebuilt as a state-sponsored centralized settlement for the relocation of the local populations who had resided as separate families in surrounding *alaas*. Due to this increase in the village population, water shortage issues became seriously apparent, and the local government decided to develop the artificial lake. According to a male informant, who was born in 1961 and now lives in Churapcha, despite this policy there has been a severe drought every 20 years in this region,[1] and the local government had implemented 42 artificial lakes during the Soviet time. Thus, one feature of the local climate is drought. These narrative results was supported by the physical data of annual rainfall fluctuation shown in Fig. 2.

According to the ethnographic survey, the river and lake ice are very important for the traditional livelihood and daily lives of Sakha people (Takakura, 2018). The interview results who that even in contemporary rural conditions, the local Sakha people usually obtain a huge amount of lake or river ice in the vicinity of the village during late October and early November for the coming year's consumption. When the temperature would be around −20 °C, they keep ice blocks in the underground storage in their residences and use throughout the year. Taking this ethnographic information into consideration, the local people might have faced severe water shortages in several years. Furthermore, if we consider that winter precipitation usually contributes to the volume of spring-thawed regional water, the low degree of winter rainfall signifies only small water resources for local communities between spring and early summer.

4.2. The ethnogeography of the thawing water stream

The local people of Khayakhsyt village told us that they had built artificial lakes to secure the thawing water as a measure against the frequent droughts. Other male informant (b. 1955) was among those who criticized that the socialist relocation policy of the 1950s brought the water shortage to the village, while each family had previously resided in their *alaas* without any water problems. He also narrated:

Therefore, our ancestors constructed the dam in the lower land to build a lake. Most of lakes in the vicinity of our village are more or less artificial, but there are roughly 300 areas of *alaas* topography, each of which is usually covered by grass and two lakes. Therefore, in total, we have 600 lakes and the village population is 600—one person for each lake—but due to the government-sponsored village relocation policy, we are always short of water.

This narrative shows that the *alaas* are regarded as the traditional water source while the artificial lake is seen as a source from the socialist era, which recalls the Sakha proverb, "We have lakes as the sky has stars. Lakes satisfy the necessities for our livelihoods" (Khabarova, 1981: 5).

There are many artificial lakes of various sizes, from small ponds to larger lakes, in the area. The technology of lake building could be regarded as somehow related to the modern civil engineering during the socialist era; however, that informant insisted that their ancestors had invented it, and it should, therefore, be called an "ethnic technology" (*narodnaia tekhnologiia*). Unfortunately, our research could not uncover the exact details; thus, this issue remains a future task for research.[2]

Our research uncovered the fact that local people had their own history of artificial lakes in their territory, regardless of whether they were created with traditional or modern technology. The technology is deeply associated with the knowledge of topography inclination and the stream of spring-thawing water from snow and ice. The local people perceived the village as a higher land among the surrounding area and believed that the spring-thawing water starts to stream down to the lower Churapcha village before flowing into the Tatta river in the Tatta district located in northeast of the village. According to the satellite information, the altitude of Khayakhsyt village is 232 m while that of Churapcha is 172 m; thus, there is a 60 m vertical difference. Fig. 6 shows a map with field interview information on local geographical perceptions inserted over a satellite image. As the map shows, residents regard that the spring-thawing water moves from their village to the lower northern land: It streams forward along Khadar village, Diring village, and Ozhulun village into the lake in the Buetueguette *alaas* and finally pours into the Tatta river. The distance between Khayakhsyt village and Churapcha village is approximately 47 km. The streaming of the spring-thawing water along such a long distance without evaporation might be associated with such soil conditions as permafrost: Generally, the degree of infiltration of water into the ground is lower in permafrost soil (Suzuki, 2013).

Local people can construct dams in some parts of the water course to build artificial lakes under the premise of their local knowledge of land inclination. Fig. 7 shows the map of the local topography based on the interviews with local residents. The image 7a represents the natural water channels in the vicinity of Khayakhsyt village in which the snow-thawing water streams in May. The image 7 b shows the artificial lake, called Targiakh, which was built in the 1950s. There is some plant population in the middle of the lake where the dam was built in the 1950s, and, at the time of writing in September 2019, it is almost submerged under water. There is a lake shore in the left side of the 7 b image, which is the dam built in the 1970s. Due to the reconstruction of this dam, the lake has been sustained. The image 7c is a snapshot of an artificial lake under construction. The villagers living nearby claimed to the local administration that their water source was too far from their houses; thus, the administration decided to construct the dam to make the lake 10 years ago. While there are small artificial lakes, there are also larger artificial lakes, such as the one in the 7 d image called Ketit lake, where there were previously 100 ha of *alaas* land in which the local administration had constructed a dam to fill water in the *alaas* topography. The average depth of this lake is 2 m. The particular history of the village is the continuous construction of artificial lakes in response to the local water shortage; the effects of such trials are shown in Fig. 7.

Furthermore, the local people have a knowledge of spring-thawing water and land inclination based on regional experiences. Fig. 8 shows this knowledge as shared by one male informant, a professional horse herder, and the GPS-recorded geographical information, through pictures taken whilst he walked with one of the authors through the area surrounding Khayakhsyt village. He remembered various types of topography, such as where a new lake formed in the 1990s (Fig. 8b), the recent appearance of permafrost-thawing resulted in land subsidence (Fig. 8c), the artificial waterway (Fig. 8d), the land subsidence caused by water discharge (Fig. 8g), and the temporarily centered thawing water (Fig. 8h). The local people have a micro ethnogeography within a few-kilometers scale surrounding their village and a macro ethnogeography and water stream knowledge from their village to Churapcha town, which totals a 50 km distance, as shown in Fig. 6. Based on this unique knowledge combination, local people have a culture of building artificial lakes.

One of the authors has continued the ethnographical research of the horse-cattle pastoralism of Sakha in particular since 2000 in a different area, the left bank of the Lena River, and has never encountered the narrative of building an artificial lake as a type of irrigation. Their irrigation might be related to the Sakha's traditional sedentarism of transhumance between summer and winter dwellings; however, this irrigation culture should be further investigated in the future.

[1] Although the local narrative recounted in our interviews insisted that severe drought occurred every 10–20 years, this did not overlap with the meteorological data. Some factors that may be related to the construction of this perception, such as difference of definition of drought and specific experience, strongly relate to the construction of perception; however, this has not been explored in this article.

[2] There is information that Sakha people traditionally owned the irrigation technology, but this has not been explored.

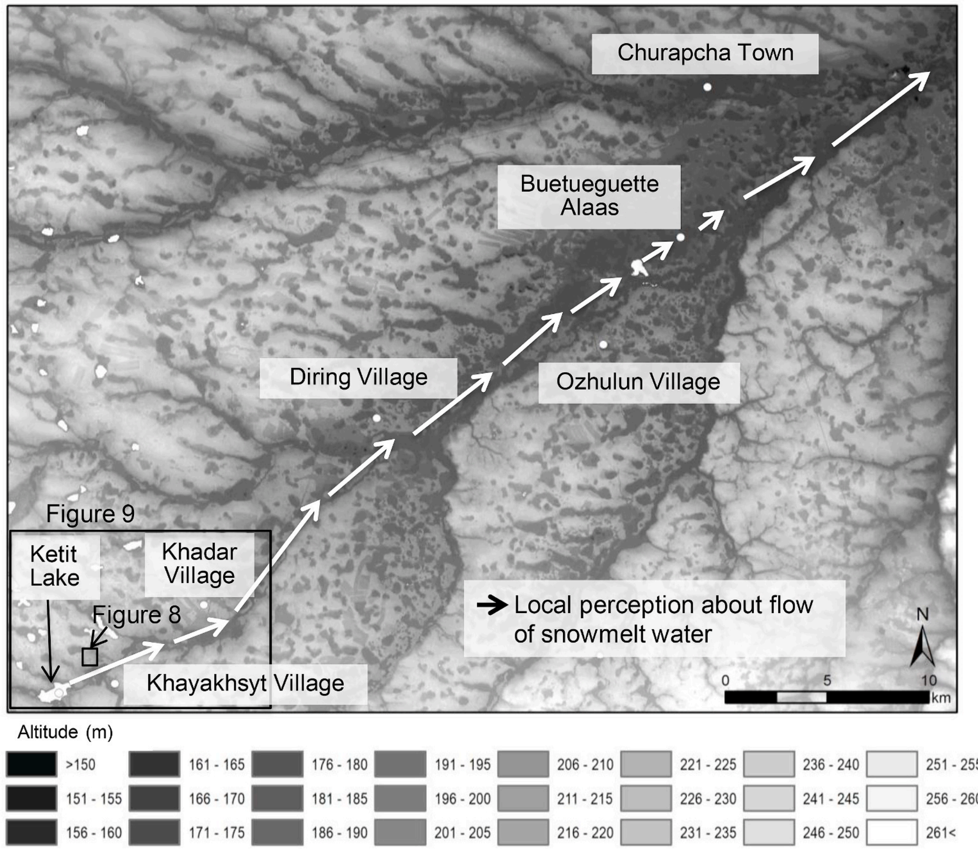

Fig. 6. Local perceptions about the flow of snow-thawed water from Kaiakhsit village to Churapcha town. Background map made by ArcGIS using 2 m DEM data of Arctic DEM (Porter et al., 2018). White patches were the pixels included error data mainly by water covered.

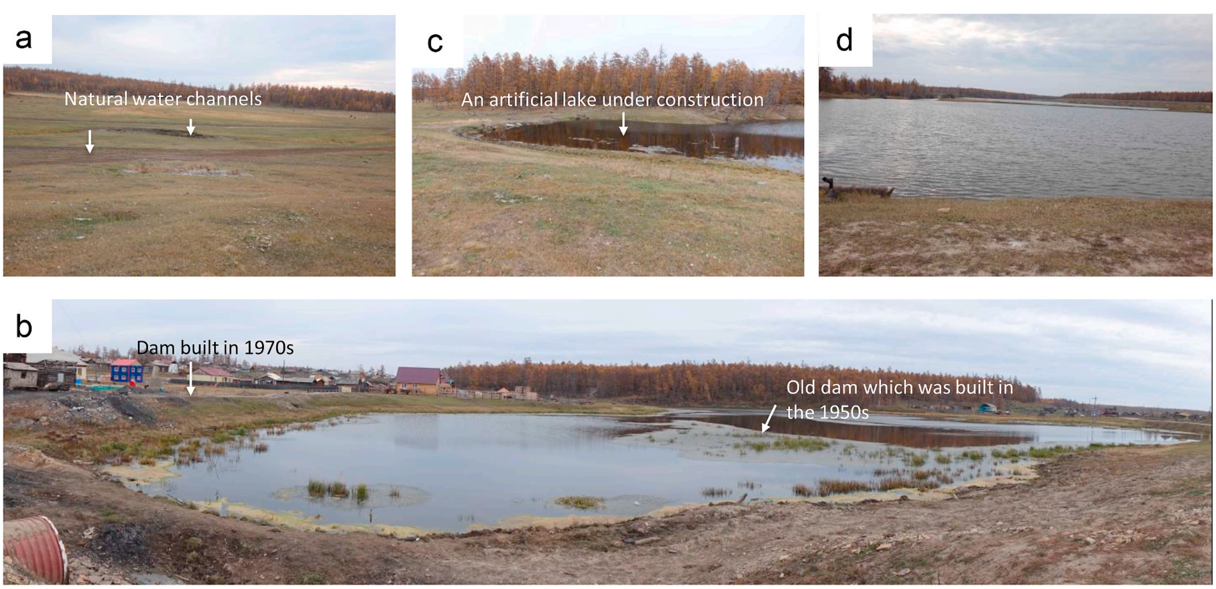

Fig. 7. Water channel and artificial lakes in the vicinity of Khayakhsyt village.
a: Natural water channel (shown by white arrow) near Khayakhsyt village.
b: Artificial lake called Targiakh.
c: Artificial lake in progress (shown by white arrow).
d: Ketit lake.

4.3. Recent changes in residents' perceptions

Fig. 9 shows a satellite image of Khayakhsyt village edited using the interview information from one male informant (b. 1981). The arrow represents the stream of the spring-thawing water: Once the water pours into Lake Ketit from the surrounding area, it moves along the arrows to

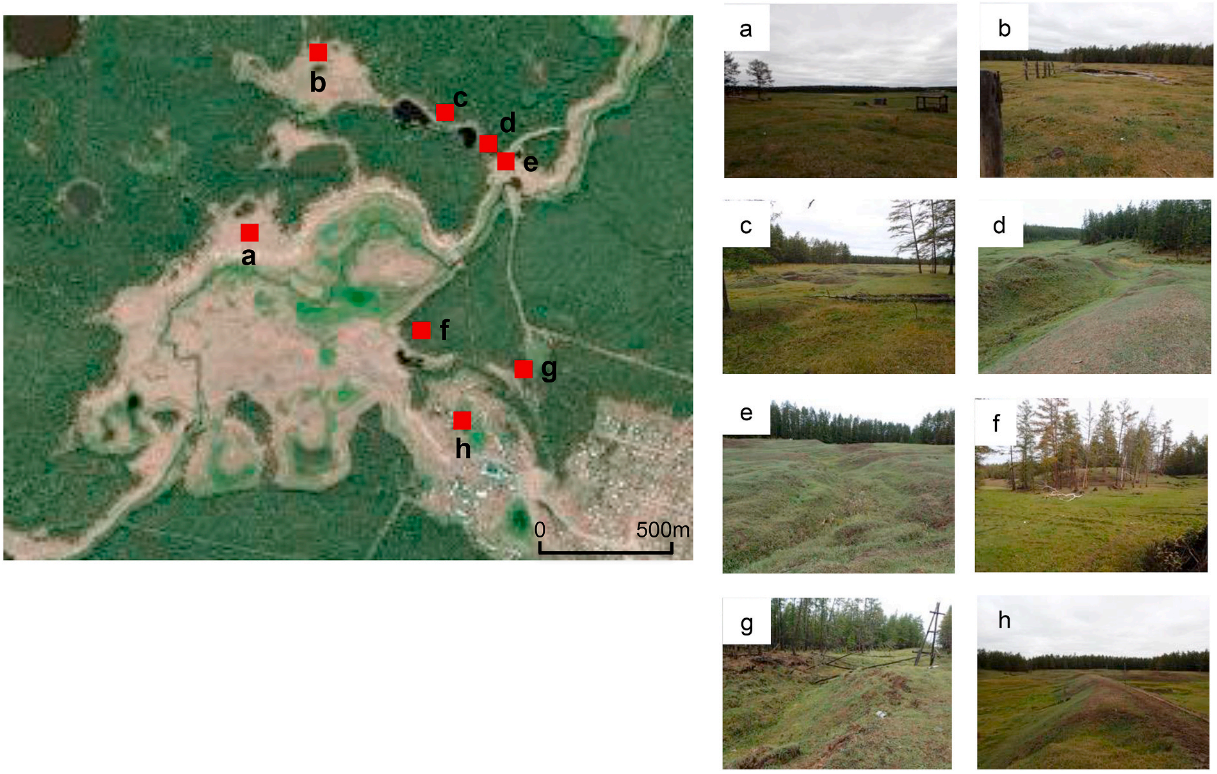

Fig. 8. Various topographical types on spring-thawing water and the land inclination with geographical information recorded by GPS receiver on a satellite image (Worldview-2 true color image products of Digital Globe Ltd.) and with local knowledge. Details of the photos are as follows:
a: An *alaas* vicinity of the village.
b: A new lake that formed in the 1990s inside of the *alaas* area of the village.
3: Former horse base (horse grazing land) in the *alaas* where recently subsidized land due to thawing permafrost (locally called *bulgunn'akh*) has emerged.
c: An artificial water way that respondents dug by themselves. The water flowed from the left side of the photo to the right.
d: The land where permafrost subsidized. There is also a snow-thawed water pathway here. In the past, this land was flat, but subsidizing began in the 1990s.
e: A *uerekh*, which is a local term meaning "small stream," is the pathway of snow-thawed water in this area. Water flows inside the forest. In this area, people had dug too many artificial ponds, so water had not flowed downstream in 1985. Some ponds were then destroyed intentionally.
f: This is a gully topography that was formed by water discharge in the summer season, not subsidizing land due to the thawing of permafrost.
g: The location where water temporarily centered in the spring season. . (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

the north. He insisted that the enlargement of lakes has appeared in Sofron *alaas*, Ebe *alaas*, and Beterueske *alaas*. The three lakes present in Sofron *alaas* that he mentioned are confirmed in Fig. 9; however, in the past, there were four lakes, and, due to the recent increase of thawing water, two lakes have merged into a larger one, which brought the decrease of grassland in the *alaas* and a subsequent drop in hay production. Note the small size of the lakes in Dugru *alaas*, which the male informant owned at the time of the interview. These lakes were originally the size of the one in Sofron.

5. Discussions

5.1. Why did two opposed perceptions exist in the village?

Although earlier research on perceptions of climate change revealed the existence of differences in perception among local people (e.g., Anisimov and Orttung, 2019; Wolf et al., 2013), this study revealed the existence of differences in perceptions within a small community in which most of the members tended to have common experiences. We add new findings: (1) local perception can be divided into groups (section 3); (2) these groups include opposite perceptions (section 3); and (3) drought is a serious focal climatic event for one group in this area even under the recent trend of precipitation increase (section 4).

Why did two opposed perceptions on climate change exist in the village? As shown in Fig. 1, the data shows that physical rainfall had increased during the prior 10 years in Churapcha and Yakutsk. Therefore, the hypothesis was that residents' perceptions of changes in rainfall patterns would be shown as increasing trends. On the other hand, this figure also shows that the fluctuation of annual precipitation is one of the features of climate conditions in this area. As shown by the interview results in section 4, there were 17 occasions of extremely small annual rainfall for 55 years.

Ayal and Filho (2017) explored farmers' perceptions of climate variability in Ethiopia and showed that more that 80% of farmers felt the various manifestations and effects of climate variability. They also demonstrated people's perceptions were found to be in disagreement with the statistical averages of meteorological rainfall trends, whereas farmers focused on extreme events relative to the effects they experienced on crop and livestock production and interpreted them qualitatively. Moreover, they pointed out that people might be influenced by recent climatic phenomena.

The main factors that affect the process of developing an individual's perception were not clarified in this study. Several factors may affect this process, but we did observe that some people were not influenced by recent climate phenomena, as they pointed out: Instead, some people's perceptions (in this case, about droughts) are not strongly affected by recent climate trends. As described in Section 4, drought and measures to ensure water security are a historical issue facing this area. This memory of drought, a part of the individual and collective knowledge, strongly remains among the community, and it might overwhelm the

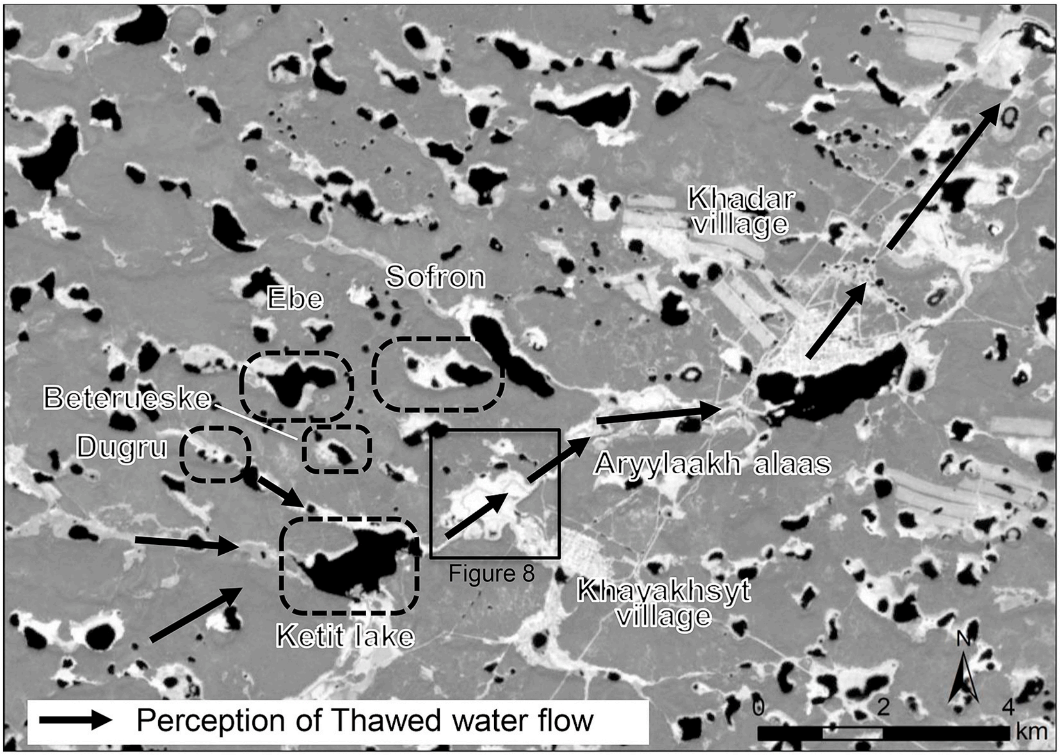

Fig. 9. Local perception about flow of snow-thawed water around Khayakhsyt village. The background map is a black and white satellite image from Sentinel-2 B and 11 (short wavelength infrared region, for clearing open-water distribution) taken on July 21, 2018. Black mainly shows the area of water coverage, while white areas mainly show grasslands.

minority perception group.

The accessibility of the different media sources or other methods of obtaining weather information might be one of the factors affecting the formation process of a respondent's perception. The focus group discussion suggested that most people obtained weather information through radio and TV, and some accessed information via the Internet through their cell phone. Also, school education was an important means for obtaining information about recent climate change. Flood and heavy rain news sometimes have been broadcast via these media in recent years, and this information might also have affected the formation process of people's perception.

5.2. How did climate change affect the perception of water resource use by residents?

Previous interdisciplinary studies on human-nature interaction in the Lena river basin across the subjects of hydro-ecology, meteorology, and anthropology have revealed that the permafrost contributes to forest formation in terms of water supply, and the gradual thawing of the permafrost, which spanned more than 6000 years, had formed the thermokarst depression locally known as *alaas* (Crate et al., 2017). The Sakha people use the gradual permafrost thawing effects to form their traditional subsistence patterns of the pastoralist-hunter complex (Crate et al., 2017). What is interesting from the case of the Churapcha region is the unique cultural formation of local knowledge in the practice of local hydrology of the spring-thawing water, the topography of inclination, and the practice of building of artificial lakes based on traditional Sakha culture. The background of this formation is the climatological effect of the instability of summer precipitation, the shortage of winter precipitation, and the un-infiltrated soil structure related to permafrost.

On the other hand, climate change and global warming may have also accelerated the local increase of precipitation, which may facilitate the residents' traditional cultural adaptations. As shown in Fig. 2, there has been an annual precipitation of less than 200 mm in the past, although years experiencing more than 300 mm of annual precipitation have appeared since the 2010s. During the interview survey, the local residents mentioned these changes as shown in Fig. 9; for example, a perception about the enlargement of lakes. As shown in section 3, however, the perception tendency contained variation, while perception strength through own experience different according to person.

5.3. How can local perception and scientific knowledge be bridged?

The Intergovernmental Panel on Climate Change (IPCC) et al., 2014 report emphasized the importance of establishing climate-resilient pathways to adapt and mitigate climate changes and their impacts and emphasized the role of environmental education (EE) in building risk management and a resilient society. Moreover, as the disturbance-resilience concept has been applied to socio-ecological systems, EE can enhance ESD (Education for Sustainable Development), which regards younger generations and local communities as important stakeholders and emphasizes the importance of bridging between scientists and education communities to promote consciousness and motivation to co-produce our future society (e.g., Krasny et al., 2010).

In the present study, local knowledge and perceptions were typically based on the community members' acquired experiences and education, which did not always correspond to scientific knowledge. However, the important point is that we have an awareness of the gap between local and scientific knowledge, and sharing information among stakeholders for knowledge co-creation can enhance our resilience to accelerating climate changes and land degradation. The making of tools and resources for EE and ESD is one role for scientists; therefore, our project (Arctic Challenge for Sustainability: ArCS) published the booklet, "Permafrost and Culture: Global Warming and the Sakha Republic (Yakutia), Russian Federation," in the Russian language in 2020, which aims to bridge perceptions and knowledge between scientists and local stakeholders, especially for the young generation (Takakura et al., 2019), which comprised the primary results of our survey questionnaire. This booklet was also distributed to the survey respondents Khayakhsyt village; the next step for mutual interaction between scientists and local stakeholders is to collect information on how people feel about the contents of booklet. We believe these trials would connect to develop climate-resilient pathways.

6. Concluding remarks

When stakeholders examine the adaptation strategies to climate and environmental changes, it is important to understand the perceptions of changes among one another. We would like to stress here that the socio-cultural and historical contexts in which perception occurs are as important as scientific data. The advantage of a questionnaire is its ability to directly obtain answers to people's true feelings corresponding to the issue that scientists are investigating, but it may fail to grasp the deep understanding of local human-nature interaction unless we integrate the local knowledge on environmental history. This study revealed that sometimes people have different or opposite perceptions and understandings of changes, even within a small community; therefore, before discussing of adaptation strategies, stakeholders should share their perceptions with each other. Gaps in perception also occasionally exist between scientists and local stakeholders: In fact, scientists sometimes view the target area in terms of their own interests or research questions, but our results revealed that local people have many other interests and issues. To establish climate-resilient pathways, these gaps in the knowledge between scientists and local people should be filled.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: This study was funded by Arctic Challenge for Sustainability (ArCS) Project (Program Grant Number JPMXD1300000000). Some of the authors participated in the projects as follows; NIHU Transdisciplinary Area Studies Project for Northeast Asia and Belmont Forum, Collaborative Reserach Action (CRA) "Resilience in Rapidly Changing Arctic Systems" with Japan Science and Technology Agency (JST).

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